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Energy Efficient Power Failure Diagonisis For Wireless Network Using Random Graph Theory

Mr. Chetan Ambekar [1], Mr. Priyesh Kotak [2], Miss. Rasika Chaudhari [3], Mr. Yoegsh Ghadigaonkar [4]
[1]Research Scholar, Dept. of Electronics & Telecommunication Engineering K. J. S. C. E., University of Mumbai, India.
[2 3] UG Student, Dept. of Electronics Engineering, K. J. S. C. E., University of Mumbai, India.
[4] UG Student, Dept. of Electronics Engineering, K. C. C. O. E., University of Mumbai, India

***Abstract*— This paper deals with the discussion of an innovative and a design for the efficient power management and power failure diagnosis in the area of wireless sensors networks. A Wireless Network consists of a web of networks where hundreds of pairs are connected to each other wirelessly. A critical issue in the wireless sensor networks in the present scenario is the limited availability of energy within network nodes. Therefore, making good use of energy is necessary in modeling a sensor network. In this paper we have tried to propose a new model of wireless sensors networks on a three-dimensional plane using the percolation model, a kind of random graph in which edges are formed between the neighboring nodes. An algorithm has been described in which the power failure diagnosis is made and solved. This paper also involves proper selection of the ideal networks by the concepts of Random Graph theory. The paper involves the mathematics of complete fault diagnosis including solving the problem and continuing the process flow.**

***Index Terms*— percolation, random graphs, sensors networks, random process, ensemble**

I. Introduction

Sensor networks are composed of a large number of tiny sensors nodes that include sensing, data processing and communicating components. These sensors autonomously establish connections via various efficient wireless communication techniques. Sensor networks have the tendency to gather the information in a certain area depends on its range by sensors and transmit it back to the observer through a sink node as defined in [4]. In any wireless network let Zigbee network, the quantities of the sensors present are very large as the area to monitor is also very large. It is quite difficult to arrange the sensors in proper manner by man power; it couldn't be able to monitor the entire region under its vicinity. So the sensors are arranged in the stochastic ways. These lead to the location of sensors and information on their neighbors being, unknowable before the network is established, which brings uncertainty and randomicity into the network. Energy of the sensor is limited in sensor networks. Therefore, one of the major goals in investigating sensor networks is to propose new innovative ways through which the power should be efficiently managed as described in [2-3], energy consumption, new routing algorithms [5], topology control methods, special MAC protocols [6] and other techniques such as data aggregation [7-9].

Modeling of the sensors becomes difficult when uncertainty in the network increases as in [13] [14]. Statically data for probability distribution is taken from [18]. In the conventional wired networks communication nodes are represented by graphs, links, nodes edges etc.

Ref. [10][11] explains about the deviation to land surface in the field of wireless medium. It is very difficult to find the exact position of the node and to know the status of links which are connecting the nodes. This situation generally arises when there is a case of a lot of networks consisting of high number of nodes, links

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thus increasing the complexity. The probability to have errors in this type of dense system is too high. So a power failure diagnosis model is made to solve the problem in the complex networks. Generally when the nodes are high deterministic modeling is difficult and some stochastic arguments are required. Suppose a sensor network with n nodes and links between the nodes are randomly arranged [11]-[14]. Some sought of probability conditions are studied in the [1]. Ref. [20] explains about the future research and challenges in the field of wireless networking. The network is modeled with a graph with n vertices fixed in advance and adding edges between random pairs with probability p. In the case we have n nodes so total there are $nC_2 = n(n-1)/2$ cases of nodes pairs having the equal probability as p to be connected to each other.
Fig. 1 shows a case in which 100 nodes are selected at random and distributed in the area of 10*10. The probability of connection between the nodes is 0.01, if seen independently then the probability is p. As there is increase in the value of p the connectedness of network goes on increasing. It has been seen through the graph below that the area where there is less connectivity is having less probability and the area where there the probability density is high the occurrence of nodes is high. A term critical probability is defined in describing the sudden change in the network selection as the probability goes above the critical probability then there is a change in the network to highly connected network. A technique is involved in which the amount of nodes over an area where the signal is to be transmitted will be given with the power and the remaining nodes will be in the off stages. This will save a lot of power as a path will be selected.
The remainder of the paper is described in the following ways: Section II gives the brief introduction regarding the related work. In section III probability concepts regarding the selection of nodes are studied. Also the concepts of Random Processes are included with time variations. In the section IV, an algorithm is described regarding the , , , probability required for the selection of path and network, also an algorithm for the power failure diagnosis is mentioned and solution for this problem is mentioned. Timing methods and delay conditions are used for detection of error. An improvement is provided regarding the power management is also given in the same section. Also some further research, problems and Matlab Simulations are provided in section V. Finally conclusion is in section VI.

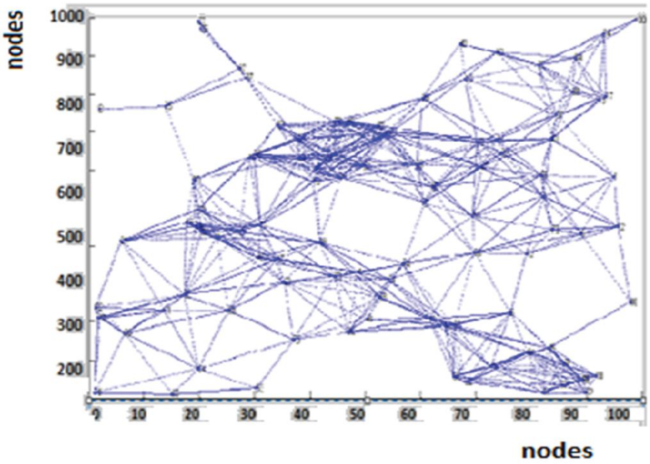


Fig. 1. (Graph representing selection of nodes for an 1000*1000 area)

II. RELATED WORK:

A. Geographical Adaptive Fidelity Algorithm:

GAF algorithm includes the selection of certain nodes based upon the geographical location of the nodes. The area which is to be monitored is divided into several small lattices forming a cluster. The size of the cluster also matters as it should meet the needs
of the communication in which the signal must flow between two farthest possible nodes.
Assume a virtual lattice square with r units on a side and denote the radio range of the sensor by R. Therefore, we get

$$r^2 + (2r)^2 \leq R^2 \quad \text{eq. 1.}$$

Here the nodes are active and inactive periodically. The node has the tendency to exchange the information from its side node after becoming active and new cluster selection occurs. Cluster head is kept active all the times but the cluster members sleep in case there is no sensing task.

B. Site Percolation:

It is a kind of random graph in which the edges are formed between two neighboring nodes. In site percolation either node is considered as an open port with a probability p or a closed port with a probability of (1-p) as described in [15-17]. Statistical analysis of probability is done in [18]. An edge exists only when there is a connection between two open ports of nodes. Site Percolations can be understood as a sudden change from the finite number of clusters to infinite number of clusters where p increases to p_c.

C. Random Graph:

A random graph consists of vertices and edges. Any two vertices share an edge with the probability of p. In Ref. [19] it has described that the probability of a random graph being connected tends to be one if the number of the edges taking part in the connection is higher than P_c= (N/2*log N). Due to this there is large change in the system performance this is phase transition in the random graph theory. The value of P_C is like a threshold value for the probability distribution as if a certain network has this sought of probability distribution then that random graph is connected. This kind of mapping technique is quite unrealistic because we have wireless edges as connection. So fair pairs of vertices need to be created, sensor has limited communication radius.

D. Random Process:

Generally in the conditions we have the case of probability distribution in which there are cases having more than one varying entity. In those cases there is a random process where variable functions are defined. These functions are called as sample functions, also when there is a single random variable as there is only one varying quantity (let s) then that it will lead to only one sample functions, but in the case if there are more than one random variable taking the case of random process then the number of functions depends on the varying quantity as it will vary for the change of both variables. Hence it will provide many sample functions. Collections of all this functions is included in a set called Ensemble, the set consists of all the functions which occurred when there is a change in the random graph.
A random variable which is a function of time is called a random process. Suppose (A, Ʊ, θ) is random variable then we can define a random process as

$$x(t) = A(s) * [\text{Ʊ}(s).t + \theta(s)] \quad \text{eq. 2.}$$

In this A(s) is the function describing the changing the random variable changing, in signal flow system we can say that it as the function for which the nodes are changed in the graph. θ(s) is the change in the phase due to the flow of the signal, Ʊ(s) is the frequency function describing the change in the frequency with the change in the node and time.
When a signal is varied with respect to time then sample function of this case will be x(t) but if there is change in only node and for a constant time we have the tendency to study the nodes then sample function will be x(s). In the same way if the case is the variation of all the two variables then sample function will be x(s, t).

III. PROBABILITY DISCUSSION:

Considering the case of a network where the nodes are randomly arranged in the form of random lattice.
Possible nodes are taken to be on the integer lattice points for simplicity. The plane vertex set is

$$Z = \{(m', n') | m', n' \ are \ integers\}$$

The actual nodes are not so aligned regularly but in order to have a simple understanding we have the case of quantized nodes. Let there be a set of n nodes, in order to send the signal from one node to another there are many ways to align a very connected network. Therefore the point is to select the way for the transferring the signal. For this case we use Bayes theorem.
Generally there are n nodes and links available for the networking will be n^2 referred to the diagram. Our goal is to find out the probability of the selection of the path from one node to other. Starting from one edge node there are two paths to select therefore the probability is 0.5, then as the nodes increase the probability of the selection of network decreases. From the figure it is cleared that when the signal moves to node two the ways to select other networks is 1/3 (0.5 if the node is corner node) each which get multiplied when the

signal moves to internal nodes. Studying the complete probability concept we have the corner nodes (nodes at corner) and mid nodes (nodes inside the lattice).

Firstly the node pair must be selected from which the signal should be transferred. For the selection of the node pair let the probability function be $P(node\ selection)$, which for an n*n square matrix will be nC_2 = $n(n-1)/2$. Let the two nodes n^{th} and m^{th} be selected for signal flow.

There are total two cases,

1. In the first case we select the pair of nodes which are at the corners. On selecting the nodes at the corners we have total 2 cases to select (total two nodes to select). Then the process continues with the selection of either nodes or two nodes as shown in the diagram fig. 2. We come up with the probability of selecting two nodes (corner) and continuing steps.
   Probability of selection of the nodes from corner a matrix and process it further for node selection
   $$= \{ \prod_{i=0}^{n}(0.5) * (2nC2\ ) \prod_{i=0}^{j}\left(\frac{1}{3}\right)\} / {}^{n^2}C_2$$
   eq.3.
2. In the second case we select the pair of nodes which are inside the matrix. On selecting the nodes we have total 2 cases to select (total two nodes to select). Then the process continues with the selection of either nodes or nodes three as shown in the diagram fig. 3. We come up with the probability of selecting two nodes (corner) and continuing steps.

Probability of selection of the nodes from inside a matrix and process it further for node selection (here n(2) means square of n)

$$= [{}^{n\,(2)-2*n}C_2 * \prod_{i=0}^{k}(1/3)] \ /\ {}^{n^2}C_2] \quad \text{eq.4.}$$

Considering the random variable as in the form of s and t

Where s = node selection.

T = time

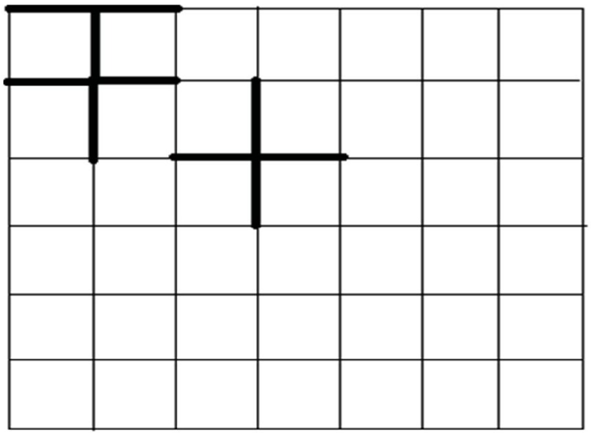


Diagram shows the technique for selection of nodes)Fig. 2

Figure shows the conditions for the corner nodes and inside nodes.

Taking the case if we have selected two nodes as a sample space and the contents of information in the form of signal is continuously changing with respect to time.

We have three cases:

1. In the first case the nodes selected are seen for a differential time interval and the time is taken as a constant value. In this case the random variable let s be changing over the selected nodes.
2. Second case takes the condition if there are nodes which are kept constant and the time is being continued to change. In all here the nodes are kept constant but the time is allowed to change. We can say that a pair of nodes are selected and study of data transmission is done for a longer period of time.
3. Third case involves the change of node as well as the time. Here there is a change in the value of the nodes (change in the random variable) also there is a change in the time. A group of nodes are

selected first and then studied for a longer period of time. Mathematically as in this case both s and t are kept varying therefore this is the case of a random process.

We involve the mathematical relations involved for all the three cases.

Case 1: Taking the case as if 2 pairs of nodes are selected at random and both the pairs are allotted with the function of time as the signal keep varying with respect to node as x_1 (s) and x_2(s).

The two functions mentioned above are the sample functions which are the part of the ensemble. Ensemble defines the collection of all the curves that can be formed by the cases of random variables. The matlab simulation in the fig. 4 shows describes the change in the node as if the node is taken as constant.

Case 2: Taking the case as if two pairs of nodes are selected at random and both pairs are allotted with the functions of time as the signal keep varying with respect to time as x_1 (t) and x_2(t). The two functions mentioned above are the sample functions which are the part of the ensemble. Ensemble defines the collection of all the curves that can be formed by the cases of random variables. The matlab simulation in the fig. 5 shows describes the change in the node as if the time is taken as constant.

Case 3: Taking the case as if two pairs of nodes are selected at random and both pairs are allotted with the functions of time as the signal keep varying with respect to time and node as x_1 (s, t) and x_2(s, t). The two functions mentioned above are the sample functions which are the part of the ensemble. Ensemble defines the collection of all the curves that can be formed by the cases of random variables. The Matlab simulation in the fig. 6 shows describes the change in the node as if the time is taken as constant.

IV. ALGORITHM:

Now the algorithm for the detection of the power failure for the signal flow in the square lattice. In the previous n*n square lattice we have total nC_2 way to select the signal flow. The major problem occurs when there is power failure then there will be loss of signal which may lead problem in order to solve this problem an algorithm is made to detect the problem and solve it automatically. Let there is a problem in the connection between the (x_i, y_i) and (x_i, y_{i+1}) node as instant power failure occurred in the region consisting these nodes then the signal can’t travel through these nodes.

There are various cases defining the probability conditions. Such as

1. Selection of the nodes which are at the corners, probability of selecting those nodes are
2. Selection of selection of nodes from inside the n*n matrix. The probability of selecting the nodes will be given as

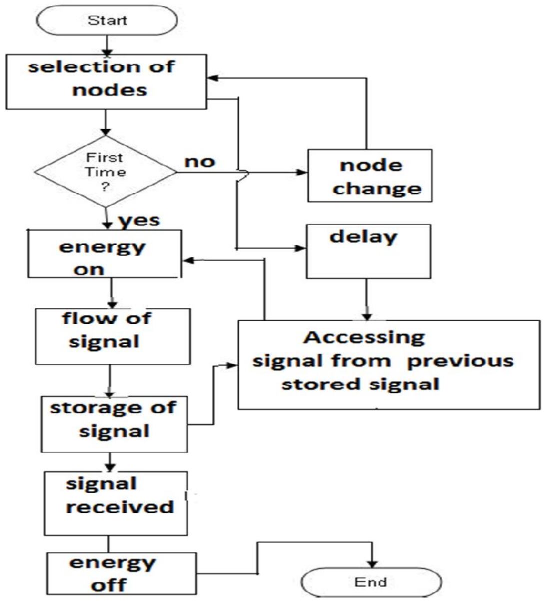
There are two major aspect of the algorithm:

1. According to our algorithm each time a node receive a signal it provides a back copy to the previous node as matter of reference that it had received the copy. This copy of received can be used at the time of power failure or node connection failure for further connection.
2. Generally there are many ways through which the signal can be transferred form one node to another but most efficient node is chosen for the transmission. Due to this there are many nodes left empty which has the less power efficiency but can be used in the case of power failure. Our algorithm describes the change in the signal flow from the failed node to the sub-node which can lead the signal to the same destination.

Algorithm:

1. Selection Of Nodes.
2. If (Very Connected)
3. Energy On.
4. Signal Starts To Flow.
5. Storge Of Signal For Small Time.
6. Else (Not Very Connected) – Node Change.
7. Repeat Step 1 (Select Node).
8. Delay
9. Accessing The Stored Signal From Previous Node.
10. Energy Off.
11. End If.

One of the major specialties of this algorithm is it will automatically dialogize the problem and tries to solve it. Also it gives the status of the problem at the destination by the mean of a delay at the destination as shown in fig. 3



(Block Diagram of algorithm described) Fig. 3

As if there is no problem there won't be any kind of delay introduced by the system and there will be a normal process flow. But if there is a problem in the node failure or power failure then there will be delay in the signal flow which leads to the delay in the streaming at the destination. By the means of this delay one can easily find out that there is a problem in the nodes or power failure in that region.

But the major problem how to know the power failure diagnosis is through probability distribution functions. We take a small model is taken into consideration and then this case is made to apply for large scale network. We take the case of a random graph containing orign, then considering the expected value of this network system when it will be large consisting infinite number of links. Let D_0 be the connected component containing the orign and denote the links by modulus of D_0. Now taking this network to a large network we take the mathematical Expectation value E (modulus of D_0).

$$E(|D0|) = \sum_{n=0}^{\infty}(n P \ |D0| = n) \quad \text{eq.5.}$$

The expected value is in the form of increasing function of probability p, and will be available as equal to infinite when the value of probability goes to p = 1. Actually the value of P is a kind of threshold which is used to decide whether there could be a condition of well-connected network. One more condition which could be used for deciding the connection of network is the taking the set of infinite network and studying the expectations of the different cases. Roughly speaking, there is a value of P_T (T stands for Temperley) which is a threshold value beyond which there is well-connected network. No doubt there is network connection before achieving P_T, but it is less and could let the signal to a loss stage. Our probability of selecting the path is also including this P_T for the selection of an efficient path.

The other problem which is generally faced by an adhoc sensor network is the power failure in the mid of the signal flow due to the fault in the power supply. But this is the natural cause as the failure due the power source is not in the hand of humans to solve. While the system could be made more efficient and fault proof, there is always some probability to have the problems in the power source. To tackle this problem the concepts of wireless energy transfer is used. This procedure gives us the method to use the energy in the form of the wireless medium in order to give power to an individual sensor network. The concept will not only reduce the probability of any power failure but also reduces the power requirement required for any sensor network.

However the range of wireless power transmission is very less as according to the laws of electromagnetics a less range is available for the transmission of energy wirelessly. This concept of wireless transmission of energy is used.

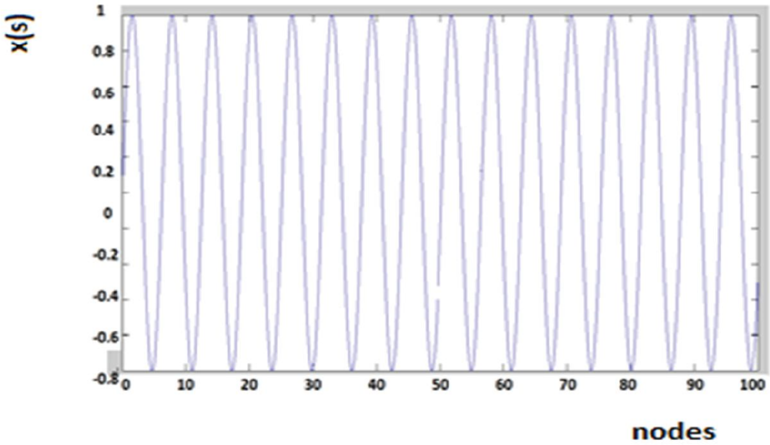
In this algorithm the concept of energy transfer is present but it includes the trigger circuit which will make a particular sensor network on only when some sought of signal has the tendency to flow through the nodes or the sensor networks.

V. SIMULATIONS:

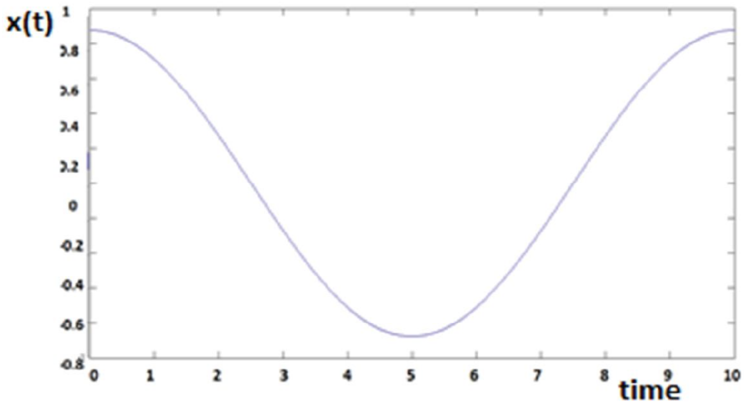
The simulation given in fig. 4 deals about the change of nodes with the function x(s) with respect to node.
The simulation in fig. 5 deals with the variation of sample function x(t) with respect to time.
This simulation given in fig. 6 deals about the changes in the random process signal as x(s, t) with respect to time as the function also varies with respect to nodes and time.
The function A(s) here is taken as sin(s). Therefore the function which is making the nodes to vary with respect to nodes is A(s). The simulation of fig. 7 deals with the changes of the signal function x(s) where the function is changing with respect to node. The function is X(s) = sin (a*s) and a is varying with respect to the nodes

VI. FUTURE RESEARCH:

This paper includes a lot of concepts of random graph theory which could be used for a lot of future research. Also the paper includes the concept through which the node selection can be made power efficient. An efficient algorithm is defined in the paper which could be used for the further research for the development of the models in the field of wireless network sensing.



Change of nodes with the function of x(s))Fig. 4

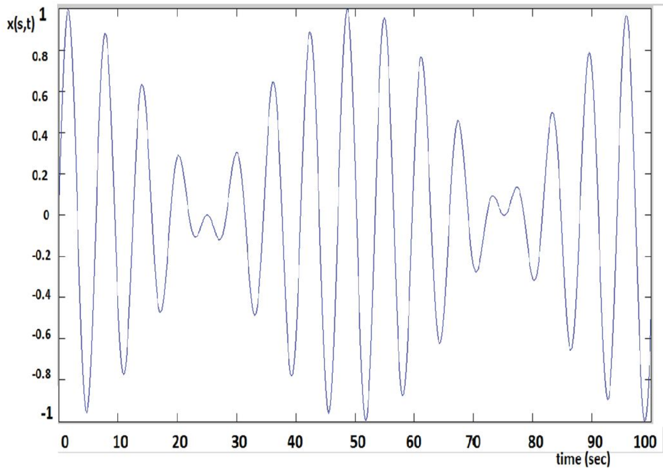


(Diagram representing the variation of x(t)with respect to time)Fig.5.

VII. CONCLUSION

We have referred the concept of random graph theory for making an algorithm on wireless sensor network. The model uses percolation theory, a kind of random graph where edges are formed only between the nearby nodes. Several conditions regarding the use of probability distribution is involved for finding out the efficient

ways for the selection of the nodes form the network. The paper has also included power saving techniques in the algorithm through which the network can be used for particular time and not all times. A lot of research work can be done in this field through which the network transmission can be more made energy efficient.



(Diagram representing change of random process with respect to time)Fig. 6

(Diagram representing change in X(s) with respect to the nodes)Fig. 7

VIII. AKNOWLEDGEMENT:

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